Imaging Performance Study: Overview

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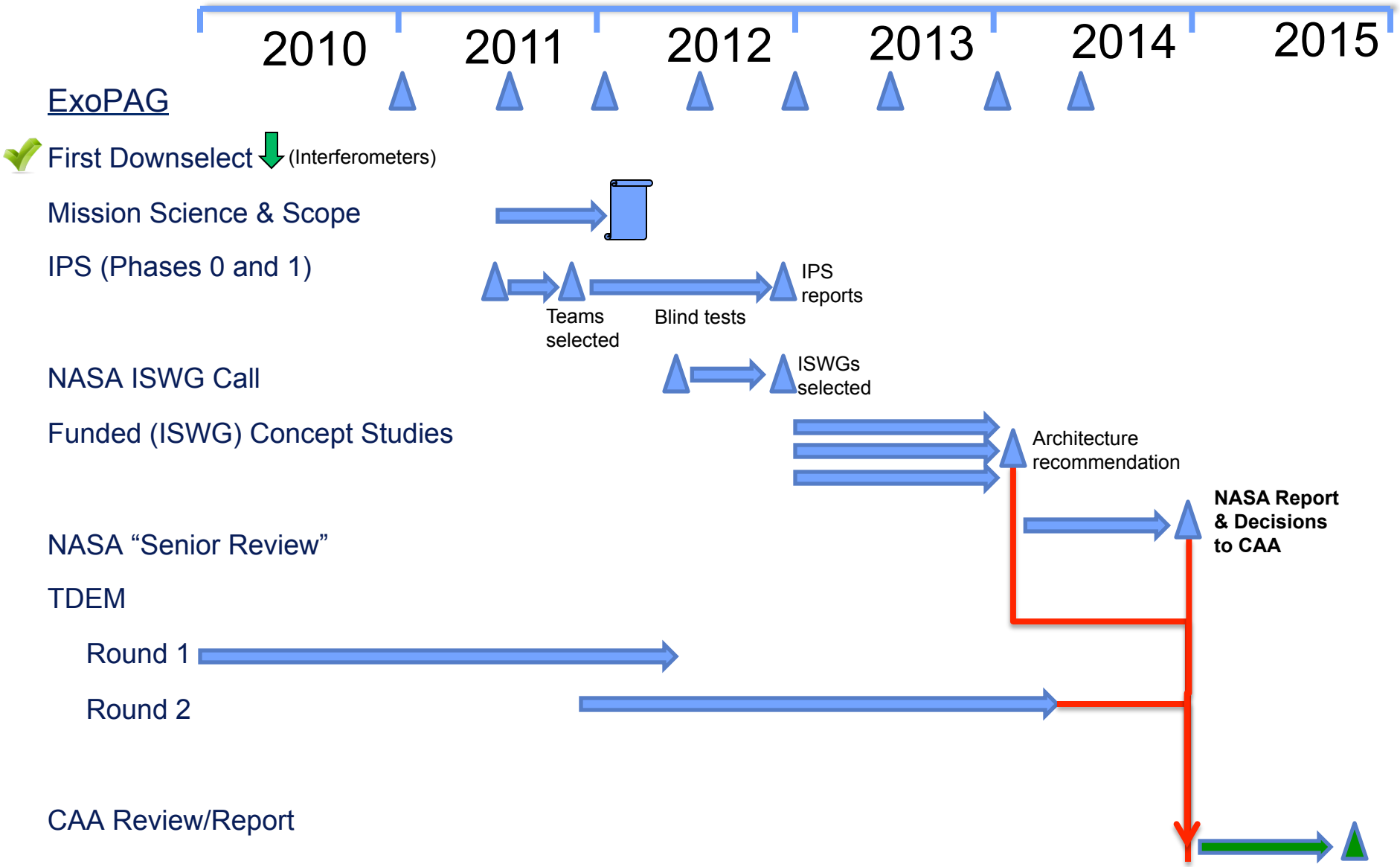
Overview

- The Imaging Performance Study (IPS) is a community-wide demonstration of simulated exoplanet detection and characterization using three direct-imaging architectures

- Intended use:
  - As a tool for the community to evaluate the science capability of three specific instrument architectures
  - To support community studies (and the ISWGs) leading to eventual recommendation of a mission architecture to the CAA in 2015

Imaging of Exoplanets: The Short-term View



Objectives of the Imaging Performance Study

- Long-term goal is to provide the community with the tools needed to evaluate the scientific capability of different “New Worlds” mission architectures
- To gain community-based experience in the analytic processes needed to pull planet signatures out of the data + noise and artifacts
- To provide a set of simulation tools for use by the exoplanet community
- Evolve sophistication of modeling effort (instrument and facility, mission operations) incrementally and through continuous interaction with the community

- Recurring theme:
  - *Engage the exoplanet science and technical community throughout this process to the maximum feasible extent*

Approach: Community buy-in at each step

- Buy-in to the process by advocates for competing architectures is essential
  - Program decisions or recommendations must represent a broad community consensus
  - We need a consensus; but unanimity not required
- "Getting onto the same page"
  - Advocates make many claims
  - Other advocates refute those claims, but make their own
  - *But it is very hard to make an objective comparison between them*
- Verification of claims
  - The operational goal of the IPS is to provide the tools with which science capabilities can be objectively evaluated
  - **The community conducts the evaluations**: the purpose of the IPS is to facilitate that process
  - In the end, it's astronomers outside of the exoplanets field that we have to convince

The IPS is a comprehensive study, but...

- The IPS is *not* intended to be an exhaustive investigation of the parameter space of any of the architectures

- The IPS is *not* a competition to select the best architecture for a direct-imaging exoplanet mission!
  - NASA will select Interim Science Working Groups (ISWGs) to perform that task

- The IPS is *not* intended to carry out a full Design Reference Mission (DRM) study at this time, but can be extended later to provide this capability when the ISWGs conduct detailed architecture trades

Organizing the IPS

- Build on the successful experience of the SIM Blind study:

- Team A designs target solar systems
- Team B creates combines stellar and planetary systems with instrument and telescope models to generate observable data
- Multiple Team Cs (selected by competitive process from broad community) assist with Team A and B tasks and then extract planets from datasets
- Team D (from combined A-C personnel) score the results

Outputs of the IPS

- The Interim Science Working Groups (ISWGs) to be selected by NASA by ~Dec 2012 will receive:
  - A set of documented IPS tools for the major architectures
  - A set of algorithms, *developed within the community*, for extracting planets from realistic (x,y,λ,time) data cubes
  - An overview of the blind tests results by the combined Team BCD groups
  - Refereed results papers by the community 'Team Cs'

IPS Plan Phases

- Pre-phase 0 – Simulation of RV and astrometric data via a GUI ('SEED')
  - Completed Dec 2010
- Phase 0 – Demonstrate simulation environment to ExoPAG-4
  - V0.0: June 2011; limited functionality
- Phase 0.5 – Develop end-to-end simulation environment
  - V0.5: ready for community use, Oct 2011
- Phase 1 – Evaluation of 3 major instrument architectures by independent community teams
  - Conducted as a 'blind test', after dry runs
  - Study period: Oct 2011 – Nov 2012
- Phase 2 – Support for *Interim Science Working Groups* (ISWGs)
  - Enhancements to simulation environment or instrument models
  - Study period: Jan-Dec 2013

Overview of Simulation Environment

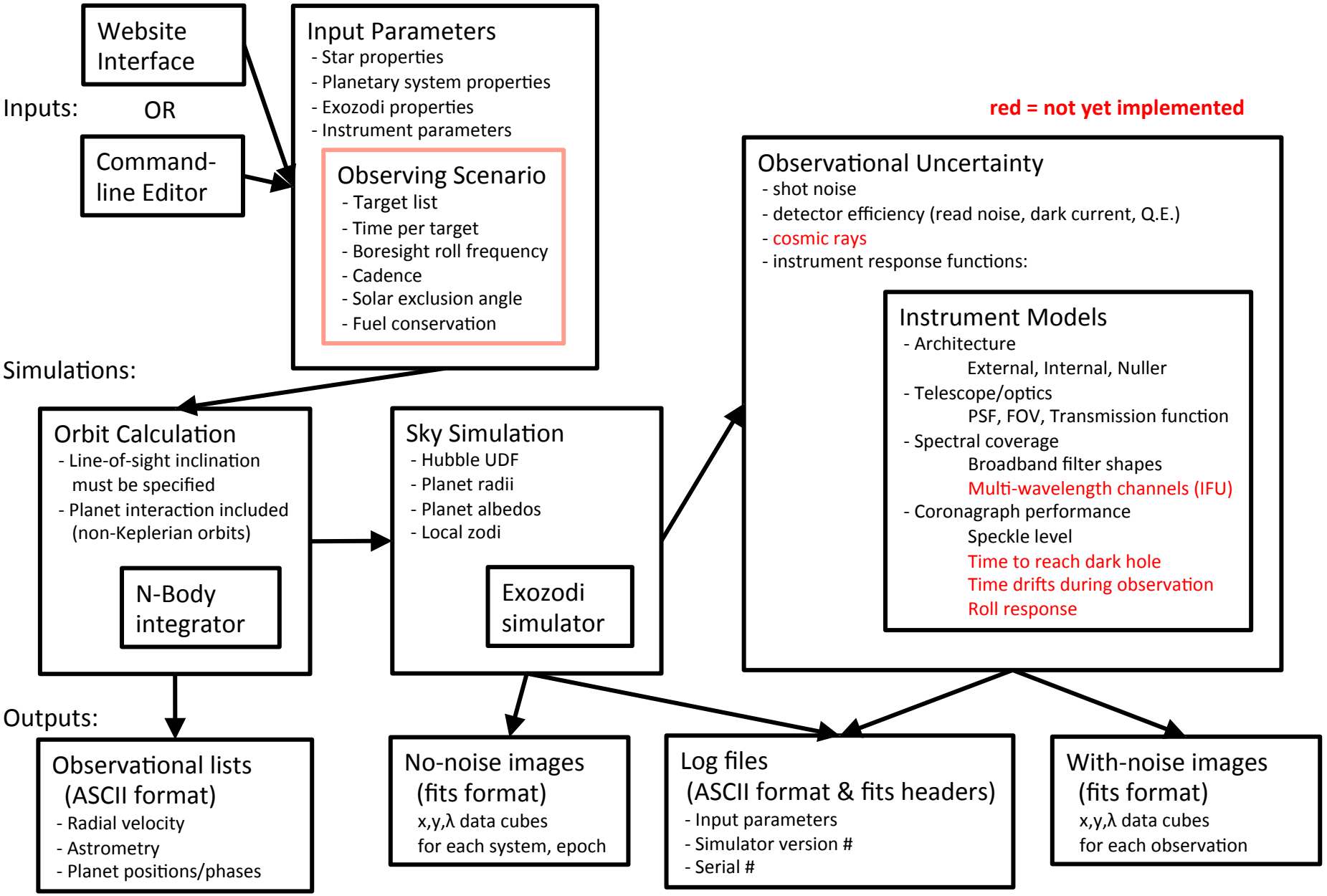
- Sky simulation:
  - Define the set of stars; planetary systems; local zodi; exozodi; background confusion (V~30 mag)
  - All the 'Team C' groups will work from the *same realization of the sky*: stars, planets, local zodi, exozodi
- Observing scenarios
  - Star visit cadence (simplified); s/c and/or starshade rolls
- Instrument simulators
  - Internal coronagraph for ~4m class telescope
  - External occulter for up to ~4m class telescope, limited maneuverability
  - Visible Nulling Coronagraph for up to ~6m segmented telescope (or 4 x 2m telescopes)
- Simulator output
  - A set of FITS data cubes (x,y,λ, time) – one for every exposure (time, roll angle, for the given cadence)
  - A log of all input parameters

Modeling Environment

- Models will run within the IPS environment
  - Simple ASCII parameter file interface
  - Web-based GUI interface
  - Output is a series of FITS (x,y,λ,time) data cubes

- Models will include realistic values of key parameters and physical limitations on performance
  - Parameters and error terms will be adopted *to roughly equalize the speckle contrast and time evolution in the image data cube*
  - IPS is designed to explore science capability for a given instrument, and the efficiency of planet-extraction algorithms, *not to pick a winner !*

IPS Architecture



Community Participation in the IPS

- Community involvement is essential
- *Your contributions are welcomed and solicited*
- End-to-end simulation process should capture the essential characteristics of each architecture:
  - Instrument models
  - Observing scenarios
  - Realistic sources of noise and systematic errors
  - Plausible planetary systems as test cases
- To the max extent possible, these should be consensus-driven
- June-October 2012 is the time period for input, while IPS V0.5 is under development

Defining IPS Instrument Models and Setting Parameters

- We plan to hold a series of telecons during the summer
  - Webex and 800-number call-in
  - Document sharing
- Telecons will be (initially) every 2 weeks for up to 2 hrs, for each of (with contact info):
  - Internal coronagraphs (John Krist)
  - Visible nullers (Bertrand Mennesson)
  - External occulters (Eric Cady)
  - Infrastructure, star and planet lists, observing scenarios (Geoff Bryden)
- Please feel free to contact these folks with suggestion and/or contributions etc.

Schedule for Community 'Team Cs'

- Aug 2011 – prepare RFP
- Early Sep 2011 – NOI for proposals to RFP
- Mid-Sep 2011 – Release RFP for community teams
- Mid-Nov 2011 – Community 'Team Cs' selected
- Early Dec 2011 – Team C meeting
- Jan 2012 – Final definition of instrument and obs parameters
- Feb 2012 – Conduct 'Open book' experiments
- Mar-Aug 2012 – Community Team Cs analyze blind test data
- Sep-Oct 2012 – JPL and Team Cs jointly evaluate results
- Nov 2012 – Team Cs write final reports
- Nov 2012 – Team Cs publish papers
- Dec2012 – Assessment Team D delivers final report

Scope of Team C Proposals

- Proposal call (RFP) in ~Sep 2011
- Duration of contracts ~Nov 2011 - ~Oct 2012
- Approximate dollar value (up to) $100k per contract
- Teams will be solicited to work with simulated data representing one of the 3 major instrument architectures
- Up to 6 teams – ideally 2 for each architecture – will be selected
- Team C work will be in four phases
  - Phase 1.1 – Dec 2011-Jan 2012 - Jointly define final instrument and observing scenario parameters; develop signal analysis software
  - Phase 1.2 – Feb 2012 – 'Open book' tests of signal analysis software and interfaces to IPS
  - Phase 1.3 – Mar-Aug 2012 – Analyze blind test datasets
  - Phase 1.4 – Sep-Nov 2012 – Assessment and publication

Backup:

Detailed Plans

Long-term objectives of the IPS

- To help the community achieve a key goal of the ASTRO2010 Decadal Survey: to detect and characterize Earth-like terrestrial exoplanets around nearby stars

- To provide the exoplanet community with the key tools needed to assess the science capability of different instrument architectures

- To help inform the choice of technologies that the Program should emphasize to enable the selection of a single approach in the ~2015 timeframe

Imaging Performance Study: Plan Phases

- Phase 0 – Develop prototype (V0.0)
  - through May 2011
- Phase 0.5 – Fully-functional (V0.5) IPS for community use
  - Jun-Sep 2011
- Phase 1 – Science capability evaluation by community teams
  - Nov 2011 – V1.0 IPS includes instrument models and key parameters agreed with community teams
  - Dec 2011-Dec 2012 – 'Blind' studies of planet extraction techniques
- Phase 2 – Interim Science Working Groups (ISWGs) conduct Concept Studies
  - Jan-Dec 2013

IPS Phase 0 – through May 2011

- Pre-Phase 0
  - Simulator for Exoplanet/Exoplanetary System Data (SEED)
    - Simulation of RV and astrometric data via a GUI
    - Released 12/22/2010
- Re-baseline WF, schedule, deliverables, cost re-plan
- Define simulation architecture in detail
  - Data interfaces, simulation modules, parameter and data logging etc. (see block diagram) – almost complete
- Major deliverable: working end-to-end simulation environment (Version 0.0) by 5/31/2011
  - Present at ExoPAG-4 Meeting
  - Includes Internal Coronagraph and External Occulter
  - Single star demonstration
  - Limited flexibility in setting parameters
  - Limited fidelity in image generation (e.g. speckle fields)

IPS Phase 0.5 – Develop IPS Version 0.5

- Major deliverable: fully functional end-to-end IPS simulation environment (Version 0.5) by 9/30/2011
  - Ready for use by data analysis Team Cs (internal and external)
  - All 3 major architectures:
    - Internal coronagraph
    - External Occulter
    - Visible Nulling Coronagraph
  - High fidelity in image simulators (e.g. speckle fields)
  - Realistic (x,y,λ,time) data cubes
  - Simplified observing campaign:
    - Observe a given list of nearby stars
    - Cadence of visits to each target, including s/c roll if necessary
  - Limited flexibility in setting input parameters

IPS Phase 0.5 schedule – Jun-Sep 2011

- ExoPAG-4, June 2011
  - Present development plan for IPS Version 0.5 ➔ 1.0
  - Discuss overall goals and schedule
  - Advertise upcoming RFP opportunity
  - Engage technical community in defining instrument models and input parameters
- Community engagement in defining instrument models
  - Ongoing: June-Sep 2011
  - Series of technical meetings, telecons, and WebEx
- Release RFP for competed data analysis groups 'Team Cs' ~Aug 2011
  - Nominally ~6 teams at ~$100k each
  - Teams may be led by advocates for specific architectures – but don't have to be
- Team Cs selected in ~Oct 2011

IPS Phase 1 schedule – Oct 2011 - Dec 2012

- Team C Orientation Workshop ~Oct 2011
  - Agree *for each architecture* on:
    - Key instrument parameters
    - Observing scenarios
      - important for estimating science yield
    - Methodology and evaluation criteria
      - important for participant buy-in
- Team Cs develop their own (proprietary) planet detection software ~Oct-Dec 2011
- IPS Version 1.0 ready by Nov 2011
  - Includes instrument models and key parameters agreed with community teams
- Conduct 'open book' experiments ~Nov-Dec 2011
  - Verify software and data interfaces to IPS
  - Verify extraction of known planet signals; check approximate SNR

IPS Phase 1 – Blind Tests

- JPL-led 'Team B' administers the blind tests
  - Use planetary systems with statistical properties defined by the previous SIM Team A study
  - Team B knows the contents of the sky input to the simulations
  - 'Double Blind' methodology not deemed necessary
    - But any JPL-internal Team C would be firewalled
- JPL and Team Cs mutually agree on simulation parameters, ~Jan 2012:
  - Planet and zodi realizations are hidden from Team Cs
  - All other info is shared between teams:
  - star lists, observing cadences (different for each architecture, and agreed in advance)
- Team Cs conduct 'blind' tests ~Jan-Aug 2012
  - Teams run their own (proprietary) planet detection software
- JPL and Team Cs jointly evaluate results by ~Oct 2012

IPS Phase 1 – Draft schedule

- Conduct ‘open book’ experiments ~Nov-Dec 2011
- Begin full simulation and analysis task ~Jan 2012
- Complete simulations by ~Aug 2012
- JPL and Team Cs jointly evaluate results by ~Oct 2012
- Team Cs write final reports by ~Nov 2012
- Team Cs publish papers by ~Dec 2012
- Assessment Team D writes IPS Report by ~Dec 2012
- ExEP delivers the IPS to the NASA-selected ISWGs in ~Jan 2013:
  - IPS Report
  - Published Team C papers and Team BCD overview paper
  - Access to IPS tool set, with documentation

Expected status at end of Phase 1

- A faithful (but not exhaustive) characterization of the science capabilities of the 3 major coronagraph architectures
  - Realistic assessment of the science yield, *if you built the instrument as simulated*
- A quantitative understanding of the SNR (etc.) needed to extract a planet signature in a variety of realistic conditions
- An set of definitions for 3 architectures for further study by the ISWGs:
  - Optical design and performance specs
  - Mission design and observing scenarios documented
  - Key technology tentpoles identified
- *These are what you'd need if you want to:*
  - Write a definitive White Paper on each design, in a non-partisan way
  - Develop a DRM (Design Reference Mission) to scope the science
  - Make a first-order grass roots/analogy cost estimate
  - Identify the driving requirements and technology needs

IPS Phase 2 – Jan-Dec 2013

- Interim Science Working Groups (ISWGs) conduct Concept Studies

- ExEP provides:
  - Infrastructure support for IPS to the ISWGs
  - Updates to IPS instrument models as needed, resources permitting
  - Support for DRM studies

Expected status at end of Phase 2

- ISWGs deliver Concept Study Reports to NASA ~ Jan 2014

- Senior Review evaluation of the Concept Study Reports conducted ~Summer 2014
  - Organized by NASA HQ
  - ISWGs present the results of their study in a face-to-face meeting with review panel
  - Discuss any issues/questions with the panel

- Senior Review Report delivered to NASA ~ Dec 2014

- Report and resultant NASA decisions fed into DSIAC in 2015
- *Green light to prepare for an ExEP mission selection in ~2020 !!*

The Very Long View: a 10 Year Planning Framework

Presented to ExoPAG-3